Journal of Crop Improvement

ISSN: 1542-7528 (Print) 1542-7536 (Online) Journal homepage: https://www.tandfonline.com/loi/wcim20

Culturally embedded practices of managing banana diversity and planting material in central Uganda

F.B.M. Kilwinger, A.M. Rietveld, J.C.J. Groot & C.J.M Almekinders

To cite this article: F.B.M. Kilwinger, A.M. Rietveld, J.C.J. Groot & C.J.M Almekinders (2019) Culturally embedded practices of managing banana diversity and planting material in central Uganda, Journal of Crop Improvement, 33:4, 456-477, DOI: 10.1080/15427528.2019.1610822

To link to this article: https://doi.org/10.1080/15427528.2019.1610822

JOURNAL OF CROP IMPROVEMENT
2019, VOL. 33, NO. 4, 456–477
https://doi.org/10.1080/15427528.2019.1610822

Taylor & Francis
Taylor & Francis Group

Culturally embedded practices of managing banana diversity and planting material in central Uganda

F.B.M. Kilwinger[a,b,c,d], A.M. Rietveld[b,c,d], J.C.J. Groot[b,d], and C.J.M Almekinders[a,d]

[a]Knowledge, Technology and Innovation Group, Wageningen University, Wageningen, The Netherlands; [b]Farm System Ecology Group, Wageningen University, Wageningen, The Netherlands; [c]Bioversity International, Kampala, Uganda; [d]Research Program on Roots, Tubers and Bananas, CGIAR, Montpellier, France

ABSTRACT

Formal seed systems aim to provide farmers with high-quality planting material that meets evolving demands and cultivation challenges. East African banana *(Musa sp.)* systems rely strongly on informal seed exchange. For seed system interventions to have a larger and more sustainable impact in such a context, it is necessary to better understand the informal seed system. We studied the management and replacement dynamics around banana suckers and mats by smallholder farmers in Central Uganda. Data were collected through Focus Group Discussions (n = 4) and semi-structured interviews (n = 23). This study showed that, on average, banana farmers grew 10 different banana cultivars to ensure year-round harvesting and to accommodate multiple consumption and cultural needs. They included cultivars from the formal seed system within their portfolios of banana cultivars while also conserving cultivar diversity. Farmers used a broad array of evaluation criteria to select suckers and preferred to use known sources to assure plant quality. Household characteristics, such as age or wealth, are determinants of mat management and replacement. We concluded that a flexible blend of formal-informal approaches to developing the banana seed system is needed to meet the multiple needs of farm households and to support them in improving productivity and dealing with emerging challenges.

ARTICLE HISTORY
Received 5 June 2018
Accepted 19 April 2019

KEYWORDS
Agro-biodiversity; genetic diversity; *Musa sp.*; seed sourcing strategies; seed system interventions

Introduction

The word agriculture combines two connected elements, "agri" and "culture", indicating that food production forms an integral part of the culture of those who grow the crops and manage the land (Pretty 2002). Seed systems are especially interesting because their combined social-cultural elements, such as the use of diversity for different purposes and the ways in which seeds are shared, reflect and shape relationships among farming people (Almekinders, Louwaars, and de Bruijn 1994; Coomes et al. 2015). Seed systems are also of interest to those who want to improve agricultural production. Access to high-quality seed is considered to be an important pathway out of poverty for smallholder farmers

CONTACT F.B.M. Kilwinger fleurkilwinger23@gmail.com

(Cromwell 1990) and is the basis of multiple development projects. To provide smallholder farmers with high-quality seed, governments, Non-governmental organizations (NGO) and other organizations concerned with agricultural development, engage in 'seed-system interventions'. These interventions are usually based on strengthening "formal" seed-supply systems, characterized by specialized organizations dealing with breeding and distribution of tested and approved varieties, applying strict quality controls (Almekinders, Louwaars, and de Bruijn 1994). Farmers in developing countries often have limited access to seed from formal seed-supply systems, which inhibits the adoption of new seed with the potential to out-perform the materials they have in their fields (Indimuli 2013; Almekinders et al. 2019). This lack of access to formal seed supplies is partly attributed to a poor understanding of the dynamics of the (informal) seed systems on which farmers rely for their seed sourcing (e.g., Almekinders, Louwaars, and de Bruijn 1994). Several authors (Cromwell 1990; Almekinders, Louwaars, and de Bruijn 1994; Louwaars and de Boef 2012; McGuire and Sperling 2015) advocated for improving the connections between formal and informal seed systems to increase farmers' access to planting materials. Almekinders and Louwaars (2002) argued that the formal seed sector should build upon, and be integrated with, existing informal (or farmers') seed systems rather than functioning in parallel to, and disconnected from, the informal sector. The first step in such integration is to understand farmers' motives and practices related to the sourcing and production of seed.

Some crop seed systems have been studied more intensively than others. Potato seed systems in the Andes and maize seed systems in Mesoamerica, for instance, have been extensively studied by both agronomists and social scientists (Keleman, Hellin, and Bellon 2009; Thomas-Sharma et al. 2015). The banana *(Musa sp.)* seed system in East Africa, by contrast, has been relatively little studied. Banana seed systems in East Africa are quite unique compared with other crops grown in the region: banana is perennial and vegetatively propagated. It has no "seed" in the strict sense of the word but is generally multiplied by uprooting the suckers, offshoots that grow around the banana stem of the mother plant that can be replanted (Robinson 1996). Moreover, East Africa has an enormous number of different banana cultivars. These factors have implications for the way farmers manage, choose, and source planting material, as it is bulky, cannot be stored and is available in relatively low quantities.

It is known that smallholder farmers in Uganda, as in many other countries, mostly obtain banana suckers from "informal" sources; farmers themselves multiply, select, and distribute the suckers (Staver et al. 2010). In this way, they access planting material that is adapted to local agro-ecological conditions and socio-economic preferences, at a relatively low cost. At the same time, the diversity of cultivars grown by farmers contributes to the in-situ conservation of banana landraces. However, there are some disadvantages associated with seed sourcing through "informal" seed systems: pests and diseases can easily build up and spread, reducing productivity and, at times, even threatening local food security, as happened with Banana Xanthomonas Wilt in East and Central Africa (Blomme et al. 2014). In addition, access to new or exotic cultivars with interesting traits is limited.

In this article, we present results of a seed system study conducted in Central Uganda, in which we studied how and why farmers maintain and value banana genetic diversity and their planting and seed-sourcing strategies, including seed selection and quality indicators. The emphasis of this study is on 1) exploring farmers' production objectives in relation to banana diversity; 2) understanding the demand for banana planting materials and how farmers share and diffuse these among themselves, and 3) gaining insights into farmers' evaluation of banana planting materials and the quality criteria they use. We discuss the findings in the light of a fast-changing context: a changing climate, the emergence of new pests and diseases, increased integration in the market economy (Bellon 1996; Rosenzweig et al. 2001; Morton 2007; Rietveld, Ajambo, and Kikulwe 2016) and threats to agro-biodiversity. We finish by proposing pathways to integrate formal seed sector initiatives into existing informal farmers' seed systems.

Materials and methods

Study area

The study was conducted in the Mukono district in Central Uganda, which borders the north of Lake Victoria and lies to the east of the capital city, Kampala. Mukono's climate is characterized by moderate temperatures, ranging between a mean annual minimum of 15ºC and maximum of 30ºC. Uganda has two rainy seasons – from March to May, and from October to December. Data were collected between September and December 2016 in five villages situated in two of Mukono's sub-counties, Ntenjeru and Nakisunga (Figure 1). The majority of the farmers in these two sub-counties are smallholder farmers although fishing, too, is an important livelihood activity in Ntenjeru sub-county. Banana is an important food and cash crop in both the sub-counties.

Study design

The study was designed to explore different elements of the banana seed system, such as cultivar use, sourcing and evaluation practices of banana planting material, through use of Focus Group Discussions (FGDs) and semi-structured interviews. The information derived from using the two methods complemented each other. The FGDs were organized to generate a cultivar inventory through the use of the four-square analysis (4 SqA) (Grum et al. 2008). The information was used to describe the diversity of banana cultivars and complemented the information on the different uses

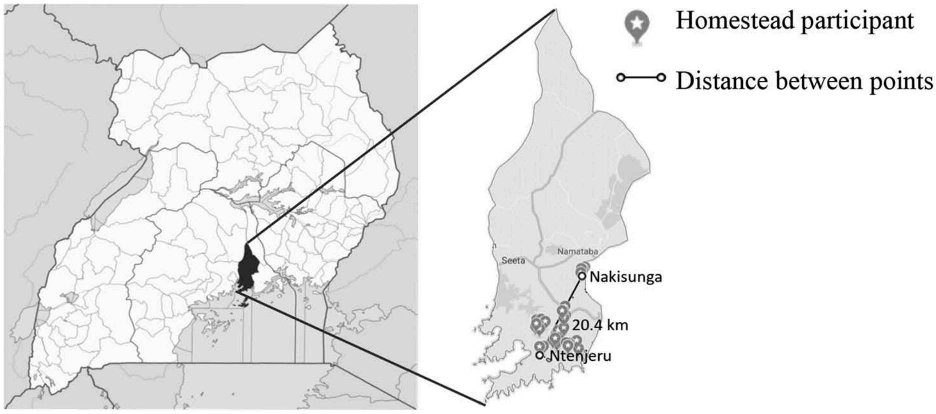

Figure 1. Map of Uganda showing Mukono district in black with a zoomed-in image of Mukono district showing the sub-counties Nakisunga and Ntnejeru and the locations of the farms where the 23 interviews were held. Sources: Adapted from Uganda Bureau of Statistics 2014 and OpenStreetMap contributors, Jarry1250, NordNordWest/Wikipedia 2018.

collected from the individual interviews. The individual interviews focused on agronomic practices and motivations of farmers. The data were partly processed quantitatively with descriptive statistics (e.g., Tables 1–6) and partly qualitative (e.g., descriptions of practices and observations, citations from farmers). The study adopted a gender-responsive design, whereby comparable numbers of men and women were included as study participants. To allow both men and women to participate comfortably and speak freely, the respondents were interviewed by someone of the same sex and participatory exercises were conducted in single-sex fashion. The data analysis was sex-disaggregated in order to bring out possible gender differences.

Four-square analysis

An adapted version of the four-square analysis (4 SqA) (Grum et al. 2008) was used to collect information on the production and use of banana cultivars. Participants were first asked to list all cultivars grown in the area. Then, use, strengths and weaknesses, year of introduction, and origin were discussed for

Table 1. Characterization of farmers in relation to their assets in housing, livestock, and landholding.

Asset	Poor	Medium	Rich
Roof type	Grass – metal	metal	metal – roof tiles
Walls	Mud – brick	Brick	Brick – plaster
Floor	Earth – cement	Cement	Cement/elevated cement/tiles
Number of cows	0	1–5	>5
Number of pigs	<2	2–10	>10
Number of goats	<4	4–15	>15
Number of poultry	<5	5–20	>20
Area of landholding	<1.5 ha	1.5–5 ha	>5 ha

every cultivar listed, after which they were each placed within a category in the 4 SqA. Each category of the 4 SqA represents the abundance in which the cultivar is grown based on area and number of households. Four single-sex FGDs were carried out, two for both men and women but with different age-groups (18–40 years and 41–70 years). For logistical reasons, all FGD participants lived in Gonvé village in Ntenjeru sub-county (Figure 1). The participants were recruited by our local key informant in the village: a lady who had previously been involved in governmental and NGO banana programs in the village. She was asked to recruit male and female farmers of different ages, economic status, and with varying amounts of areas planted with bananas. The FGDs, held in October 2016, involved 6–8 participants and lasted for 2–3 h.

Interviews and surveys

A total of 23 semi-structured interviews were conducted with individual male and female farmers from households of different wealth classes. Interviewees were selected purposefully by directly approaching people in the village and knocking on doors, with the aim of selecting a representative sample relative to socio-economic status and agro-ecological conditions. The interviewees were then characterized on basis of: type of house, livestock owned, farm type, size of banana plantation, sex, and age. They were selected from Gonvé and four other villages, all situated in the sub-counties of Ntenjeru and Nakisunga. There was little socio-economic and agro-ecological variation among the villages and the maximum distance between interviewed households was 20 km. By including farmers from a somewhat larger area, we wanted to increase the validity of our study, specifically in relation to identifying seed sources (farms, farmers) and flows. Each interview lasted 2–3 h and followed the same protocol. First, we collected data on the farm and household, cultivation practices and input use, and then we discussed "banana-specifics" while "walking the farm". During this walk, details, including cultivar name, age, origin, and management information, were recorded for a maximum of 16 banana mats. Thus, data on sourcing of 279 individual banana mats were collected. The mats were selected as follows: Four mats of four cultivars from each farm were sampled, with, wherever possible, one cultivar fitting within each square of the 4 SqA. The farmer was asked to first show us the oldest mat of the cultivar and end with the youngest. The last part of the interview addressed sucker management and farmers' perceptions of the desired qualities of planting materials.

Data analysis

The results of all four FGDs were combined to provide an overall picture of the uses and diversity of banana in the area. They were also compared to identify gender, age-group or wealth-specific differences. The farmers participating in the interviews were classified based on sex of the household head, age, and wealth. Farmers aged 18 to 30 years were classified as young farmers, those between 31 and 50 years as middle-aged and those aged over 50 as old. Wealth classification was constructed on the basis of household assets and resources: type of house, the number of livestock, and area of landholding (Table 1). The interview data were entered and coded in Excel and analyzed according to the frequencies of answers to identify trends and patterns. For some questions, numerical answers were given and these were analyzed using descriptive statistics (sums, means, standard deviation, and ranges). The qualitative data were used to support and explain visible trends in the quantitative data.

Results

Household and cultivation characteristics

Of 10 women interviewed, six were heads of their household, which meant, de facto, that they were single and no adult male was living in the house (Table 2). The other 17 households were defined as male-headed by the interviewees, and four women respondents thus belonged to a male-headed household. All but one of the male respondents were married and living with their wives. The cultivated area under banana ranged from 0.1 to 2.4 ha per household. Young farmers and single women mainly had less area under bananas. The area under banana among poor households was also lower (median = 0.2 ha), with the exception of one farmer who cultivated 1.2 ha. He did not own the land but was allowed to farm on it by a wealthy man from Kampala. The mean area under bananas of wealthier households was about double that of the medium wealthy and poor households. The age of

Table 2. Socio-economic characteristics of farmers and properties (size and age) of their banana plantation. Mean, Standard Deviation (SD), and Range are presented.

					Size banana plot (ha)			Age banana plot (years)		
Characteristics of interviewed farmers	n	Men (n)	Women (n)	Mean age	Mean	SD	Range	Mean	SD	Range
Sex of household head										
Male headed households	17	13	6	48	0.73	0.59	0.1–2.4	20	15	2–46
Female headed households	6	0	4	44	0.37	0.28	0.1–0.8	17	19	4–45
Age										
Old farmers	11	6	5	58	0.68	0.40	0.1–1.4	31	14	9–45
Middle aged farmers	7	4	3	44	0.77	0.81	0.1–2.4	13	8	2–25
Young farmers	5	3	2	27	0.36	0.38	0.1–1.0	4	2	2–7
Wealth										
Rich households	7	6	1	50	1.04	0.73	0.1–2.4	20	17	2–45
Medium wealthy households	11	6	5	47	0.43	0.30	0.1–1.0	19	14	2–46
Poor households	5	1	4	43	0.53	0.46	0.1–1.2	20	20	2–45
Total	23	13	10	47	0.64	0.55	0.1–2.4	20	16	2–54

the banana plantation (calculated as the number of years since establishment) ranged between 2 and 54 years, with a mean of 20 years. Younger farmers had younger banana plantations than older farmers.

All interviewees confirmed both men and women were involved in banana production. The majority of households intercropped bananas with coffee and/or legumes (beans). Households consumed approximately half of banana produce and sold the other half to local traders. In all households, banana was among the three most important crops for income generation. Inputs, such as manure, were mainly acquired from their own farm. The most common pesticide used was Rocket (Cypermethrin- a pyrethroid insecticide), which was applied by eight farmers against banana weevils.

Diversity of banana cultivars

FGD participants identified 30 different banana cultivars (Table 3) and 10 more cultivars were mentioned in the interviews. Interview respondents grew an average of 10 different banana cultivars on their farms and this was independent of respondents' sex, age or wealth status. Most cultivars (≈75%) identified in the FGDs belonged to the endemic East African Highland Banana (EAHB) group, also known as *Musa* AAA-EA (Karamura, Karamura, and Tinzaara 2012). Cultivars belonging to each of the five major clonal sets in this group (Mbidde, Musakala, Nakitembe, Nfuuka, and Nakabululu; see Karamura, Karamura, and Tinzaara 2012) were grown. Participants also mentioned cultivars from more recently introduced genotypes, such as *Musa* AAA groups, the *Musa* ABB group, plantains (AAB), apple bananas (AAB) and hybrid lines (FHIA). Table 3 contains a summary of FDG participants' responses in relation to "the abundance of the cultivar in the community" and "the year of introduction". Answers on "abundance" varied among the four FGDs: the most-frequently mentioned categories are shown in Table 3. Participants in the FGDs identified 22 indigenous and eight "introduced" cultivars. Some cultivars identified as "introduced" by the elder age-groups were not recognized as such by those in the "youth" FGDs. This was, for instance, the case for the cultivars Kisansa and Kayinja, which are thought to have been introduced 40–50 years ago. Several more recently introduced cultivars, such as Lwadunga and AGT, were only mentioned in the youth FGDs. Three different sources of the introduced cultivars were identified: two government agencies; the National Agricultural Research Organization (NARO) and The National Agricultural Advisory Services (NAADS) and a private-sector company, Agro Genetic Technologies Ltd (AGT). Half of the cultivars listed and categorized in square 1 of the abundance analysis (grown by many farmers on a large area) consisted of introduced cultivars. These cultivars (such as Mpologama and Kisansa) were appreciated for their big bunches and high yields.

Table 3. Four square analysis of banana cultivars and their abundance, type and year of introduction estimated by farmers in Gonvé village. Cultivars with a symbol are recognized as introduced by different groups.

Square 1. Many farmers – Large area			Square 2. Many farmers – Small area		
Local cultivar name	Type of banana	Year of introduction	Local cultivar name	Type of banana	Year of introduction
Bogoya	Dessert	Indigenous	FHIA† ‡ § ¶	All	1998
Tombadala	Dessert	2006	Kibuzi black	Cooking	Indigenous
Kibuzi	Cooking	Indigenous	Kivuvu	Cooking	Indigenous
Kisansa ‡¶	Cooking	1970	Musakala	Cooking	Indigenous
Mpologoma † ‡ § ¶	Cooking	2000	Muvubo	Cooking	Indigenous
Nakitembe	Cooking	Indigenous	Ndiizi	Dessert	Indigenous
Square 3. Few farmers – Large area			**Square 4. Few farmers – Small area**		
Local cultivar name	Type of banana	Year of introduction	Local cultivar name	Type of banana	Year of introduction
			AGT †	Cooking	2004
			Bogoya red	Dessert	Indigenous
			Gonja	Roasting	Indigenous
			Kayinja ‡¶	Beer	1970
			Kisubi	Beer	Indigenous
			Luwaata	Cooking	Indigenous
			Lwandungu †	Cooking	2011
			Mbidde	Beer	Indigenous
			Mwazirume	Cooking	Indigenous
			Nakabululu	Cooking	Indigenous
			Nakawere	Cooking	Indigenous
			Nakytengu	Cooking	Indigenous
			Nambi	Cooking	Indigenous
			Namwezi	Cooking	Indigenous
			Nandigobe	Cooking	Indigenous
			Nsalwagiri	Cooking	Indigenous
			Nfuuka	Cooking	Indigenous
			Ndiizi Mfungu †	Dessert	1998

† Cultivar is recognized as introduced by young men
‡ Cultivar is recognized as introduced by older men
§ Cultivar is recognized as introduced by young women
¶ Cultivar is recognized as introduced by older women

Each of the cultivars mentioned had one or more main use(s): brewing, cooking, roasting or dessert bananas. Cooking and dessert cultivars were represented in squares 1, 2, and 4, but brewing and roasting type cultivars were only placed in square 4 “grown by a few farmers on a small area”. None of the cultivars was consistently placed in square 3 “grown by a few farmers on a large area”; only the young women placed the cultivars Mpologoma and Kisansa in square 3. They pointed out that some varieties could be represented in more than one square because they were grown by large-scale farmers in large quantities but could sporadically be found on the farms of small-scale farmers as well. Some cultivars were identified by farmers as extinct or nearly extinct in the area. Mostly the production of brewing cultivars, such as Kisubi, Kayinja or Mbidde, had declined in recent years, mainly as a result of high susceptibility to Banana Xanthomonas Wilt (BXW).

Use and socio-cultural significance of banana cultivars

The classification of bananas into cooking, dessert, roasting, and beer types only indicates the main use of the banana bunch. Other parts of the banana plant are also used; the pseudostem is used as animal fodder, packaging, and mulch, and its fibers are used to make fire, ropes, mats and baskets. Banana leaves are used for mulching, for packaging, and in food preparation when food is steamed. The participants often mentioned this last use of leaves as important. Not all cultivars produce suitable leaves for steaming food. Bogoya and Ndiizi were mentioned as having good leaves for steaming as they gave the food a nice aroma and a yellow color. Some cultivars are valued for their medicinal properties; Gonja is used to hasten the healing of new-born babies’ navels and Mbidde to prevent vomiting. Bananas are also associated with many cultural traditions, ceremonies, and rituals. It is traditional to bring a banana bunch (or several if you are wealthy) to social gatherings, such as weddings, and to drink banana-beer. When a baby girl is born, the placenta is buried under a mat of Nakitembe and a baby boy's placenta under a mat of Mbidde or Kayinja. The placenta is viewed as a twin of the newborn baby and requires a respectful burial. The practices of cultivation are also subject to traditional rules and beliefs: the plantation is almost considered a living organism, which requires respect. As one female respondent said:

> “Because the banana plantation knows me, I am the only person uprooting suckers from my plantation. If I were to allow fellow farmers to uproot in my garden, I might anger my plantation. Whenever I want to uproot suckers, I first inform my plantation I am going to take some of her children away. I do so by cutting off the tops of a few suckers the night before I want to uproot. It is a kind of ‘death announcement’ that I make to the plantation before taking the children away.”

Cultivars are generally also arranged in specific patterns within the plantation. Food cultivars are traditionally grown in mixtures. There should be at least one mat of Mbidde (beer banana) in the middle of the plantation as this cultivar represents *"the man of the plantation"*. Some cultivars, considered to be "bad neighbors" to other cultivars, are planted at the edges of the plantation, such as Bogoya, Ndiizi, and Gonja. Gonja is also placed at the boundaries, as it is said to protect the plantation against thieves. Some farmers grow dessert and brewing cultivars on remote fields in more extensive management styles.

Banana suckers and the replacement dynamics of banana mats

Bananas are tree-like perennial herbs that do not have a fixed lifespan (Robinson 1996). Farmers estimated the lifespan of banana mats to vary from five years for the Nandigobe and Mpologoma cultivars (Both EAHB-AAA) to 83 years for the Bogogya cultivar (AAA). However, many farmers claim that, under the right conditions and management, a banana mat can live forever as new suckers keep regenerating, which is referred to by the farmers as the mats "continuity". Disease infestation, unfavorable climate conditions or poor management can cause a banana mat to decline in productivity or die. Declines in the productivity of banana mats are generally attributed to "the age of the mat", "pests and diseases", "competition from other banana mats" or "declining soil fertility". One male farmer explained that the soil has a great influence on a mat's productive lifespan:

> "Bananas are very soil selective and that is why different cultivars are preferred in each area and their lifespans vary. I take the soil type into account on my farm. Through trial and error, I have come to understand my soil and know which cultivars thrive well in which parts of my farm."

Low-performing mats can be replaced by uprooting them and replacing them with a new sucker. Similarly, a new sucker can be planted in the gaps left by a mat that has died or created by the movement of mats.[1] Because of the practice of mixing different cultivars in the plantation, the differences in strengths and weaknesses of the cultivars and the high on-farm diversity of cultivars used, it is very rare that large areas of banana mats show a decline in productivity or die at the same time. Thus, the plantations are kept vital in two ways: 1) by managing an existing mat in such a way that it keeps regenerating and 2) by planting banana suckers to fill gaps in the plantation, or replacing unproductive mats (Figure 2). Farmers follow different strategies when gap-filling and replacing banana mats. Some actively uproot mats showing a decline in productivity and replace them with a new sucker, whereas other farmers only fill gaps that occur naturally through the death or movement of a mat. This decision mainly relates to the farmer's ability and willingness to invest labor, as uprooting a banana mat is labor-intensive. For this reason, female farmers and older male farmers in our sample tended

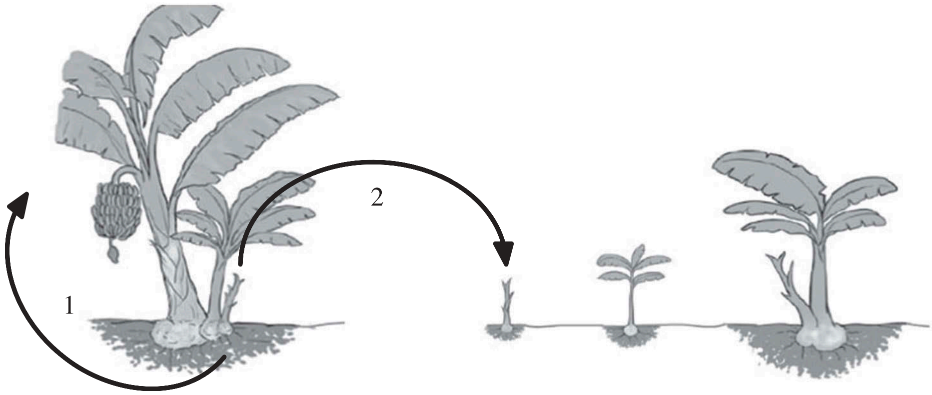

Figure 2. Two ways to maintain the vitality of a banana plantation. 1: Under favorable circumstances and proper management a banana mat continuously produces new suckers. These suckers will follow up on the mother plant after a bunch has been harvested. 2: A new banana mat can be established by uprooting a sucker from the mat and planting it elsewhere. The sucker will eventually grow into a new banana mat. Source: Adapted from Wairegi et al. 2016.

not to uproot and replace low productive mats. When the research team pointed out to one of the female farmers that she had a mat infected with BXW on her farm she replied: *"I am too tired to uproot these diseased mats and the disease keeps coming back anyway"*. Gender norms, which prescribe uprooting as "men's work", might also play a role in women's consideration not to uproot (Rietveld 2017).

The need for suckers and how farmers source them

Since farmers only plant a whole area when they are expanding or establishing a plantation, gap-filling tends to be more common. This has consequences for the need for suckers or planting material. Gap-filling tends to happen in a haphazard fashion, whenever a gap occurs, suckers are available and the soil is humid enough. Most farmers could not recall the exact number of suckers they planted during the previous rainy season (the April rains of 2016). Many farmers said they had faced a shortage of suckers on their farms because of prolonged droughts in the 2015–2016 planting seasons. On average, farmers estimated having planted 19 suckers, i.e., 52 suckers per hectare during the April planting season. The number of suckers available for planting from their own plantation was estimated at 5 to 300 by the farmers, which translates to a mean of 189 suckers/hectare (Table 4). Farmers considered a sucker to be "available for planting" when it was not needed for the continuity of the mat from which it was to be extracted and when it was of sufficiently good quality. More details about farmers' perceptions of sucker quality are described in the next section. Young farmers generally had more suckers available than older farmers. Farmers estimated

Table 4. Farmers' estimations of the numbers of suckers planted/ha during the last planting season, the estimated number of suckers available for planting/ha and the percentage of those suckers the farmers expect to need for planting on their own farm. Mean, Standard Deviation (SD), and Range are presented.

		Number of suckers planted			Number of available suckers/ha†			Percentage of suckers needed on farm (%)†		
Characteristics of interviewed farmers	n	Mean	SD	Range	Mean	SD	Range	Mean	SD	Range
Male-headed households	17	38	42	0–124	147	157	12–519	72	34	0–100
Female-headed households	6	67	137	3–346	266	242	16–692	67	29	33–100
Old farmers	11	17	31	0–109	72	77	12–177	87	24	40–100
Middle-aged farmers	7	79	120	5–346	181	128	41–371	71	29	33–100
Young farmers	5	63	52	10–124	381	285	49–692	43	31	0–71
Rich households	7	22	35	0–99	107	100	19–247	80	28	40–100
Medium wealthy HH's	11	76	99	0–346	208	170	12–518	67	38	0–100
Poor households	5	13	7	5–25	244	288	16–692	65	28	33–100
Total	23	46	76	0–346	189	193	12–692	70	31	0–100

†The sample size for these questions was smaller since it was not included in the first five pilot interviews (n = 17), see Table 6 for n per group.

that they needed 70% of their available suckers for filling gaps and replacing mats in the coming season, but this figure varied widely among them. About half of the farmers needed 100% of their own available suckers for replanting, whereas one young farmer expected not needing any suckers in the coming season.

Seed sourcing practices

Of the 279 sampled banana mats, 59% originated from suckers from existing banana mats on the farmers' own farms. Sometimes the banana mats were already in place when the farmers obtained rights to the land/banana plantation (referred to as "inherited" in Figure 3). Farmers also sourced planting material from friends, relatives, and neighbors. Seventy percent of the mats sourced off-farm were a gift, the remainder 30% included a monetary transaction ranging between 500 and 1500 UGX (≈US$ 0.15–0.40). Only 14 mats (circa 5%) had been sourced from the formal seed system, mostly via NAADS, the government extension program.

All farmers preferred to source suckers from existing mats on their own farm because they were familiar with these plants and could thus predict performance, properties and pest and disease status of the sucker. There were three main reasons why farmers sourced suckers from elsewhere: 1) insufficient suckers available on their own farm; 2) interest in other cultivars, and; 3) seeing high performing bananas (bearing big bunches) on someone else's land. When sourcing from their own farm, farmers selected suckers on the basis of the condition of the mat, the mother plant and the sucker itself. When sourcing

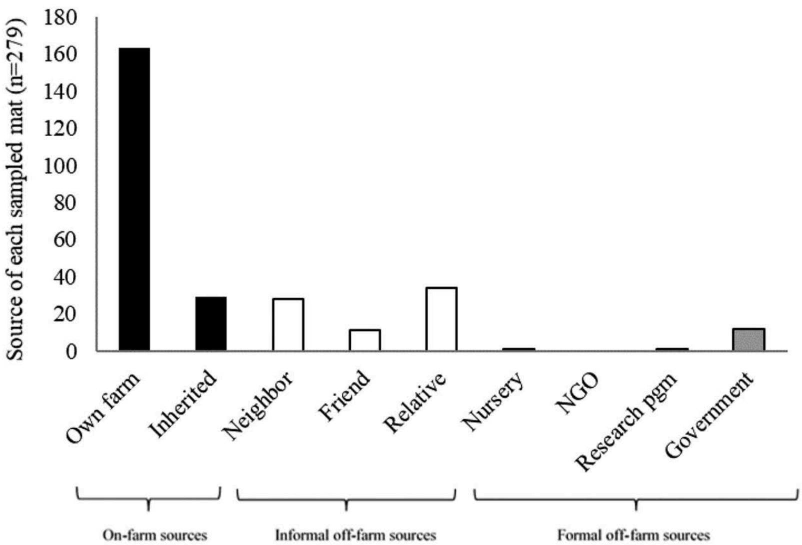

Figure 3. Source of each sampled mat (n = 279). Black bars are on-farm sources, white bars informal off-farm sources and grey bars formal off-farm sources.

from elsewhere it is often not possible to see the mat or mother plant as the suckers are usually uprooted and sometimes even pared[2] by the source-farmer. Farmers thus miss reliable information (other than the source farmers testimony) about the sucker and even might not be sure which cultivar they are sourcing. Sometimes source-farmers would allow a receiving farmer to select suckers in their plantation but generally only if they were close relatives or friends or when a monetary payment was involved. Decisions on where, or from whom, to source suckers were based on multiple criteria, such as the presence of pests and diseases, the management of the source-farmer and types of cultivars grown on the farm (Table 5).

About half of the farmers claimed having a surplus of available suckers on-farm and thus the ability to provide suckers to others. Only a minority of 8 out of 23 farmers had shared suckers in the last rainy season (Table 6) and the maximum number of suckers shared per farmer was 200. The mean number of suckers shared per ha for all respondents was 17 and for only those farmers that actually shared suckers it was 76 per ha. Old farmers were less likely to share, and shared fewer suckers than other groups. Although both men and women from all wealth statuses claimed to share suckers, several poor farmers said they never received suckers from fellow farmers. One of the poor female heads of household explained: *"I do not receive suckers from fellow farmers because I cannot share or sell suckers myself. If someone came to me now to ask for suckers, I would not even have one available. People around here only want to sell suckers to me for 1000 UGX (≈ 0.30\$)".*

Table 5. Criteria of farmers in their decision for an off-farm source and number of farmers naming each criteria (n = 23).

What do you take into consideration when choosing an off-farm source?	n†
The presence of pests and diseases on the farm	15
The way a the farm is managed and if the farm is in a good condition	9
The bunch sizes on the banana mats on the farm	8
The types of cultivars that are grown on the farm and how they would perform on my own farm	4
The reputation of the farmer	4
The age of the plantation	1
Total	41

† Farmers could mention more than one criterium.

Table 6. Number of farmers who provided suckers to other farmers last planting season, the absolute number of suckers they provided and the number of suckers provided/ha (n = 17). The number of suckers shared among only the farmers who shared is also given/ha (n = 8). Mean, Standard Deviation (SD), and Range are presented.

			Number of sucker shared (total)†			Number of sucker shared/ha (total)†			Number of suckers shared/ha (sharers)‡		
Characteristics of interviewed farmers	n	Farmers that shared (%)	Mean	SD	Range	Mean	SD	Range	Mean	SD	Range
Male-headed households	11	45	21	50	0–200	24	52	0–173	83	68	8–173
Female-headed households	6	50	8	12	0–30	32	58	0–148	64	73	15–148
Old farmers	6	17	1	4	0–12	1	3	0–8	8	0	8–8
Middle-aged farmers	7	57	45	73	0–200	53	64	0–148	92	58	15–148
Young farmers	4	75	13	17	0–35	46	72	0–173	76	84	27–173
Rich households	5	60	34	74	0–200	17	31	0–82	39	38	8–82
Medium wealthy households	7	29	10	24	0–75	27	61	0–173	148	35	124–173
Poor households	5	60	9	13	0–30	39	63	0–148	64	73	15–148
Total	17	47	17	44	0–200	26	52	0–173	76	65	8–173

† The mean number of suckers shared including the farmers which did not share, giving them a value of 0.
‡ The mean number of suckers shared among only the farmers who actually shared suckers.

Farmers' perceptions of the quality of banana suckers

Farmers assess the quality of a sucker destined for planting before they uproot it, on the basis of a range of traits of the mat, the mother plant and the sucker itself (Table 7).

The traits most frequently mentioned related to the sucker itself, viz., leaf shape and size, pseudo-stem shape, sucker size, and weevil damage. Leaf shape and size, pseudo-stem shape, and sucker size indicate age and nature of the sucker and determine if a sucker is a "sword" or "water" sucker. The distinction between these two types of suckers can therefore be considered the main criterion for farmers, who prefer sword suckers and dislike water suckers, often referring to them as "abnormalities". Water suckers are young suckers with a thin, straight pseudo-stem that have developed big and broad leaves. One of the farmers described them as follows: *"They are like a 4-year*

Table 7. Characteristics taken into account while selecting a sucker and the number of farmers naming each characteristic (n = 23).

	Characteristic	n†
Sucker	Leaf shape and size	14
	Shape of the pseudo stem	13
	Size of the sucker; Weevils and/or boreholes in corm/stem	9
	Color of the leaves	6
	Health of the sucker	5
	Color pseudo stem	4
	Position of leaves along the pseudo stem; Number of leaves	2
	"Ash" on the base of the leaves; Cigar leaf coming up vertically; Reddish color on the base of the leaves; Depth of the roots; Color of corm after paring	1
Mat	Continuity (number of mother plants, followers/children, and suckers/grandchildren on the mat)	5
	Age of the mat	2
	Place on the mat where sucker appears; Distance between the sucker and the mother plant; Corm of mat above soil surface or not	1
Mother plant	Bunch size given by mother plant	6
	Weevil infection of mother plant	5
	Health of mother plant	4
	Diameter pseudo stem of mother plant	2
	Size of fingers of mother plant	1

† Farmers could mention more than one trait.

old boy with a beard, if you saw a boy like that you would just know that something is wrong inside". Sword suckers, by contrast, have a cone-shaped pseudo-stem with a broad base and spear-shaped leaves. The number of water suckers generally increases with the age of the mats, as they become shallower, which results in a smaller connection between the mother corm and the sucker (Robinson 1996). This might explain why older farmers seemed to have fewer available suckers (Table 5).

The mat trait most frequently mentioned by farmers was the regeneration or continuity of the mat, referring to the number of growth cycles a mat has been through. Farmers can enhance the continuity of the mat by leaving the "right" number of suckers on the mat. They explain that removing too many suckers weakens the mat and drives it to an early death. On the other hand, leaving too many suckers on the mat can reduce productivity, as the suckers draw on the available carbohydrates. "De-suckering" is therefore a common management practice (Robinson and Nel 1990). Judging the "right" number of suckers to be left on the mat depends on the farmers' management style and on the cultivar. Most farmers compared the plants on one mat to a family; the oldest plant on the mat, which produces a bunch first, is referred to as the mother, the second-largest or eldest plant is called the daughter and the suckers following that are the grand-children. According to those farmers, a mat needs a mother plant, one daughter and at least two vital grand-children (suckers). This often means that the best suckers are kept on the mat to ensure its continuity, and are not available for replanting. The implication is, for an optimal management regime, at least four vital suckers should be present on the mat before it can be considered ready to provide any planting materials.

Not all farmers named the same number of traits for selecting a sucker, nor did all farmers take the mat and mother plant into account. This was sometimes not necessarily attributable to a lack of knowledge but, rather, out of necessity, as healthy, vital suckers can be scarce. One woman, head of a poor household, explained:

> "I know there are more characteristics to look at while selecting a sucker, but I do not take those into account. None of my suckers would pass those criteria anyway so why should I use them? For me it is most important that the suckers are free of diseases, if they are, I plant them."

Discussion

Farmers in Mukono district maintain high on-farm banana cultivar diversity because of the multiple end uses of the different cultivars but also because the diversity in strength and weaknesses reduces production risks. Low-yielding cultivars can be retained because of other superior traits, such as good taste or because they have a certain cultural value. Farmers have adopted newly introduced, higher yielding cultivars, such as FHIA and Mpologoma, by integrating them in their portfolio of cultivars. This process of testing and adding banana cultivars, rather than displacing them, has been described earlier by Gold et al. (2002). The introduction of new, potentially superior banana cultivars can threaten agro-biodiversity and *in situ* conservation of traditional cultivars (Tripp 1996), as has happened with maize, rice, and wheat (Keleman, Hellin, and Bellon 2009; Chaudhary et al. 2004; Tsegaye and Berg 2007). In Mexico, the loss of diversity of maize has been attributed to the reduced relevance of specific end-uses (Keleman, Hellin, and Bellon 2009). Since multiple end uses of bananas are a key driver for maintaining diversity, similar genetic erosion might occur among Ugandan banana farmers if their needs or production objectives change. For instance, as farmers become increasingly linked to the cash economy and markets, productivity can become the primary objective and other end-uses (e.g., steaming, medicine, packaging) become of less relevance since products, such as plastic and pharmaceuticals, can be accessed elsewhere.

Another reason why newly introduced cultivars, even when considered by farmers as superior, might not be adopted on a large scale in a short timeframe, can be found in banana's unique replacement dynamics. Farmers normally aim to extend the lifespan of their banana mats, which means that a proportion of the good quality suckers remains on the mat and that there are relatively few good suckers potentially available for planting and exchange. In addition, most farms have a mixture of banana cultivars and therefore a substantial number of suckers of a single cultivar is rarely available. Climate variation can also influence sucker availability. For example, the previous growing season had been exceptionally dry, and farmers had insufficient sucker supplies.

Large amounts of planting material are usually only required when a new farm is established or when the farm is expanded. Once a banana plot is established, farmers prefer to fill gaps in the plantation that occur because the banana mats die or move, rather than re-planting the whole plot. This, in combination with several factors, makes the demand for planting material highly irregular and difficult to predict. These factors include the perennial nature of bananas, the high on-farm diversity of cultivars, differences in strengths and weaknesses of cultivars, and the differences in mat replacement management among farmers. Although planting material from farmers' own farms is preferred for gap filling, farmers also source suckers off-farm if they need more suckers than are available on their own farm, or when they want to add a new cultivar. When doing so, farmers holistically evaluate the sucker, the mother plant, the mat, the farm, and the management of the source farmer. This means that farmers (irrespective of gender, age or wealth status) prefer to source planting materials from within their own social networks. Exchange of planting material is often mentioned as a common route for pest and disease transfer (Tenkouano et al. 2006; Staver et al. 2010; Kikulwe 2016). However, the relatively low frequency of planting material exchange, in combination with a holistic approach of quality evaluation, makes it less likely that all pests and diseases are transferred on a large scale via the exchange of planting material. It is plausible that other ways of disease transfer, such as insect transmission and the exchange of tools, are responsible for the fast spread of some pests and diseases. Therefore, the fact that some farmers are unable or reluctant to uproot diseased mats might pose a large risk to disease spread because they form a source of infection for surrounding farms. Keeping the banana mats small by de-suckering could facilitate removal of diseased mats, as it requires less physical strength. Further research on pest and disease transfer could clarify if this assumption is true and thereby improve strategies to reduce the spread of pests and diseases.

Some farmers pointed out that limited availability of quality planting materials from their own farms and social networks forces them to use sub-standard planting material. Social networks have proven to provide quite a successful mechanism for distributing improved varieties of seeds of several crops, such as wheat, rice, beans, and potato (Cromwell 1990; Dorward et al. 2007; Ronner, Almekinders, and van Heerwaarden 2016; Tadesse et al. 2016). This suggests that it is important to study and understand flow of planting materials through social networks. Seed-system studies have also highlighted that wealthy farmers are more likely to act as a source of planting materials than poorer farmers (Sperling and Loevinsohn 1993; Subedi et al. 2003; Tadesse et al. 2016) as they are more likely to have surplus planting material, whereas poor farmers are more likely to have chronic shortages (McGuire 2008). Our study found that men and women of all wealth classes provided suckers to fellow farmers. While there were differences in sucker availability, our limited sample size was insufficient to determine if, and the extent to which, gender and wealth status (or other social factors) play a role in determining on-farm seed surpluses or shortages. As explained earlier, there are several reasons why both sucker availability and demand are very variable between planting seasons. Therefore, our "one-season snapshot" is insufficient to identify which farmers function as a seed-source or to understand the rules that guide seed exchange. To address this, and the mechanisms that underpin the exchange of planting materials, more comprehensive research would be needed across multiple planting seasons.

Conclusions and recommendations

Increasing farmers' access to high quality, clean seed of preferred cultivars is an important way of improving banana productivity and profitability. Yet, high on-farm genetic diversity, differences in the lifespan of banana mats, the variability in replacement dynamics among different types of farmers and the difficulty in storing banana suckers make it extremely challenging to design and run interventions that effectively enhance banana productivity.

Interventions geared toward improving banana seed systems in Central Uganda need to adopt a long-term perspective and recognize the imperative of patience. The perennial nature of banana, the cultural preference for the longevity of plantations and the multiple end uses to which bananas are put, coupled with the large labor investment required in uprooting existing mats, mean that the adoption of new cultivars progresses slowly. Development initiatives should be wary of defining "success" as the large-scale replacement of landraces with new cultivars. Not only do data suggest that farmers value high on-farm diversity for multiple reasons, but the *in situ* conservation of banana cultivars is valuable in itself and is beneficial for the formal seed sector in the long run (as a reservoir of genes/traits).

The diversity of banana cultivars in central Uganda is maintained by a variety of mechanisms. Social ones, such as food and nutritional security, and multiple consumption, functional and cultural uses, play a key role, as do biological ones: the multiplication of bananas via suckers, and the difficulty in storing them, does not allow for large quantities of a similar cultivar to be available at any given time. The introduction of new and faster multiplication methods, such as tissue culture, could provide large quantities of a single cultivar and thus increase access to new and clean planting material but at the same time could narrow the number of cultivars grown. Moreover, because of farmers' preferences for maintaining diverse plantations and their holistic way of assessing quality (mainly based on trust within social networks), farmers might well be hesitant to adopt these new types of planting material. Interventions will have to offer convincing arguments or strategies to interest farmers in paying for planting materials that look very different than those they are used to and will not only have to prove that their materials are “superior” but also teach farmers how to assess and manage the new material and build up a relationship of trust.

Notes

1. Gaps in the plantation can also be created by “movement” of mats: because each sucker comes up a few inches away from the mother plant, the mats move with every cycle, eventually creating new spaces in the plantation.
2. Paring (or peeling) suckers involves cutting the roots from the corm and cutting off the top of the sucker. This is done by some farmers to remove diseases attached to the corm and to make sucker more easily transportable (Lwandasa et al. 2014).

Acknowledgments

This research was undertaken as part of, and partly funded by, the CGIAR Research Program on Roots, Tubers and Bananas (RTB) and supported by CGIAR Fund Donors (http://www.cgiar.org/funders/). The authors thank Winifred Candiru and Francis Kalyongo, the field assistants, for their work in collecting the data and Charles Staver, Aman Bonaventure Omondi and Lucy Ann Mulugo from Makarere University for their suggestions and advice in the design phase of this study. We also like to thank Vincent Johnson and Nick Parrott for their skillful English language editing and the reviewers for their constructive comments. Our gratitude goes out to all the men and women who participated in the study for their knowledge, openness and kindness.

Disclosure statement

No potential conflict of interest was reported by the authors.

Funding

This work was supported by the CGIAR Research Program on Roots, Tubers and Bananas;

Data availability statement

The data set can be obtained from Fleur Kilwinger via email: fleurkilwinger23@gmail.com

ORCID

C.J.M Almekinders http://orcid.org/0000-0001-9779-5150

References

Almekinders, C. J. M., and N. P. Louwaars. 2002. "The Importance of the Farmers' Seed Systems in a Functional National Seed Sector." *Journal of New Seeds* 4 (1–2): 15–33. doi:10.1300/J153v04n01_02.

Almekinders, C. J. M., N. P. Louwaars, and G. H. de Bruijn. 1994. "Local Seed Systems and Their Importance for an Improved Seed Supply in Developing Countries." *Euphytica* 78: 207–216. doi:10.1007/BF00027519.

Almekinders, C. J. M., S. Walsh, K. Jacobs, J. Andrade-Piedra, M. McEwan, and S. de Haan. 2019. "Why Interventions in the Seed Systems of Root, Tubers and Bananas Crops Do Not Reach Their Full Potential." *Food Security* 11 (1): 23–42. doi:10.1007/s12571-018-0874-4.

Bellon, M. R. 1996. "The Dynamics of Crop Infraspecific Diversity: A Conceptual Framework at the Farmer Level." *Economic Botany* 50 (1): 26–39. doi:10.1007/BF02862110.

Blomme, G., K. Jacobsen, W. Ocimati, F. Beed, J. Ntamwira, C. Sivirihauma, F. Ssekiwoko, et al. 2014. "Fine-Tuning Banana Xanthomonas Wilt Control Options over the past Decade in East and Central Africa." *European Journal of Plant Pathology* 139 (2): 271–287. doi:10.1007/s10658-014-0402-0.

Chaudhary, P., D. Gauchan, R. B. Rana, B. R. Sthapit, and D. I. Jarvis. 2004. "Potential Loss of Rice Landraces from A Terai Community in Nepal: A Case Study from Kachorwa, Bara." *Plant Genetic Resources Newsletter* 137: 1–18.

Coomes, O. T., S. J. McGuire, E. Garine, S. Caillon, D. McKey, E. F. Demeulenaere, D. Jarvis, et al. 2015. "Farmer Seed Networks Make a Limited Contribution to Agriculture? Four Common Misconceptions." *Food Policy* 56: 41–50. doi:10.1016/j.foodpol.2015.07.008.

Cromwell, E. 1990. *Seed Diffusion Mechanisms in Small Farmer Communities: Lessons from Asia, Africa and Latin America*. London: ODI.

Dorward, P., P. Craufurd, K. Marfo, W. Dogbe, and R. Bam. 2007. "Improving Participatory Varietal Selection Processes: Participatory Varietal Selection and the Role of Informal Seed Diffusion Mechanisms for Upland Rice in Ghana." *Euphytica* 155: 315–327. doi:10.1007/s10681-006-9333-y.

Gold, C. S., A. Kiggunda, D. A. Karamura, and A. M. Abera. 2002. "Selection Criteria of *Musa* Varieties through a Farmer Participatory Appraisal Survey in Uganda." *Experimental Agriculture* 38: 29–38. doi:10.1017/S0014479702000133.

Grum, M., E. A. Gyasi, C. Osei, and G. Kranjac-Berisavljevic. 2008. *Evaluation of Best Practices for Landrace Conservation: Farmer Evaluation*. Rome: Bioversity International. Accessed 13 December 2018. https://www.bioversityinternational.org/fileadmin/_migrated/uploads/tx_news/Evaluation_of_best_practices_for_landrace_conservation__farmer_evaluation_1308.pdf

Indimuli, L. 2013. *Factors Influencing the Discontinuance in Adoption of Tissue Culture Banana Technology: A Study of Smallholder Farmers in Maragwa District*. Institute for Development Studies, University of Nairobi. Accessed 18 January 2019. http://erepository.uonbi.ac.ke/bitstream/handle/11295/59240/Indimuli_Factors%20influencing%20the%20discontinuance%20in%20adoption%20of%20tissue%20culture%20banana%20technology.pdf?sequence=3&isAllowed=y

Karamura, D. A., E. B. Karamura, and W. Tinzaara. 2012. *Banana Cultivar Names, Synonyms and Their Usage in Eastern Africa*. Kampala: Bioversity International.

Keleman, A., J. Hellin, and M. R. Bellon. 2009. "Maize Diversity, Rural Development Policy, and Farmers' Practices: Lessons from Chiapas, Mexico." *The Geographical Journal* 175 (1): 52–70. doi:10.1111/geoj.2009.175.issue-1.

Kikulwe, E. 2016. "Banana Tissue Culture: Community Nurseries for African Farmers." In *Case Studies of Roots, Tubers and Bananas Seed Systems. CGIAR Research Program on*

Roots, Tubers and Bananas (RTB), edited by J. Andrade-Piedra, J. W. Bentley, C. Almekinders, K. Jacobsen, S. Walsh, and G. Thiele, 185–250. Lima: RTB Working Paper No. 2016-3.

Louwaars, N. P., and W. S. de Boef. 2012. "Integrated Seed Sector Development in Africa: A Conceptual Framework for Creating Coherence between Practices, Programs, and Policies." *Journal of Crop Improvement* 26 (1): 39–59. doi:10.1080/15427528.2011.611277.

Lwandasa, H., G. H. Kagezi, A. M. Akol, J. W. Mulumba, R. Nankaya, C. Fadda, and D. I. Jarvis. 2014. "Assessment of Farmers' Knowledge and Preferences for Planting Materials to Fill-Gaps in Banana Plantations in Southwestern Uganda." *Uganda Journal of Agricultural Sciences* 15 (2): 165–178.

McGuire, S. 2008. "Securing Access to Seed: Social Relations and Sorghum Seed Exchange in Eastern Ethiopia." *Human Ecology* 36: 217–229. doi:10.1007/s10745-007-9143-4.

McGuire, S., and L. Sperling. 2015. "Seed Systems Smallholder Farmers Use." *Food Security* 8: 179–195. doi:10.1007/s12571-015-0528-8.

Morton, J. F. 2007. "The Impact of Climate Change on Smallholder and Subsistence Agriculture." *Proceedings of the National Academy of Sciences* 104 (50): 19680–19685. doi:10.1073/pnas.0701855104.

OpenStreetMap contributors, Jarry1250, NordNordWest/Wikipedia. 2018. Accessed 16 January 2019. https://en.wikipedia.org/wiki/Mukono_District#/media/File:Mukono_District_in_Uganda.svg

Pretty, J. 2002. *Agri-Culture: Reconnecting People, Land and Nature*. London: Earthscan.

Rietveld, A. M. 2017. "Gender Norms and Agricultural Innovation: Insights from Uganda Sustainable Intensification in Smallholder Agriculture: An Integrated Systems Research Approach." In *Sustainable Intensification in Smallholder Agriculture. An Integrated Systems Research Approach*, edited by I. Oborn, B. Vanlauwe, M. Phillips, R. Thomas, W. Brooijmans, and K. Atta-Krah, 289–303. London: Earthscan.

Rietveld, A. M., S. Ajambo, and E. Kikulwe. 2016. "Economic Gain and Other Losses? Gender Relations and Matooke Production in Western Uganda." Paper presented at Tropentag, Vienna, 18–21 September 2016. Accessed 4 December 2018. http://www.tropentag.de/2016/abstracts/full/542.pdf

Robinson, J. C. 1996. *Bananas and Plantains*. Wallingford: CAB international.

Robinson, J. C., and D. J. Nel. 1990. "Competitive Inhibition of Yield Potential in a 'Williams' Banana Plantation Due to Excessive Sucker Growth." *Scientia Horticulturae* 43: 225–236. doi:10.1016/0304-4238(90)90094-U.

Ronner, E., C. J. M. Almekinders, and J. van Heerwaarden. 2016. "Tracing Seed Diffusion from Introduced Legume Seeds through N2Africa Demonstration Trials and Seed-Input Packages." Accessed 6 February 2019. https://n2africa.org/sites/default/files/Tracing%20seed%20diffusion%20from%20introduced%20legume%20seeds%20through%20N2Africa%20demonstration%20trials%20and%20seed-input%20packages.pdf

Rosenzweig, C., A. Iglesias, X. B. Yang, P. R. Epstein, and E. Chivian. 2001. "Climate Change and Extreme Weather Events: Implications for Food Production, Plant Diseases, and Pests." *Global Change and Human Health* 2 (2): 90–104. doi:10.1023/A:1015086831467.

Sperling, L., and M. E. Loevinsohn. 1993. "The Dynamics of Adoption: Distribution and Mortality of Bean Varieties among Small Farmers in Rwanda." *Agricultural Systems* 41: 441–453. doi:10.1016/0308-521X(93)90044-3.

Staver, C., I. van Den Bergh, E. Karamura, G. Blomme, and T. Lescot. 2010. "Targeting Actions to Improve the Quality of Farmer Planting Material in Bananas and Plantains – Building a National Priority-Setting Framework." *Tree and Forestry Science and Biotechnology* 4 (1): 1–10.

Subedi, A., P. Chaudhary, B. K. Baniya, R. B. Rana, R. K. Tiwari, D. K. Rijal, and D. I. Jarvis. 2003. "Who Maintains Crop Genetic Diversity and How?: Implications for On-Farm Conservation and Utilization." *Journal of Culture and Agriculture* 25 (2): 41–50. doi:10.1525/cag.2003.25.2.41.

Tadesse, Y., C. J. M. Almekinders, R. P. O. Schulte, and P. C. Struik. 2016. "Tracing the Seed: Seed Diffusion of Improved Potato Varieties through Farmers' Networks in Chencha, Ethiopia." *Experimental Agriculture* 53 (4): 481–496. doi:10.1017/S001447971600051X.

Tenkouano, A., S. Hauser, D. Coyne, and O. Coulibaly. 2006. "Clean Planting Materials and Management Practices for Sustained Production of Banana and Plantain in Africa." *Chronica Horticulturae* 46 (2): 14–18.

Thomas-Sharma, S., A. Abdurahman, S. Ali, J. L. Andrade-Piedra, S. Bao, A. O. Charkowski, D. Crook, et al. 2015. "Seed Degeneration in Potato: The Need for an Integrated Seed Health Strategy to Mitigate the Problem in Developing Countries." *Plant Pathology* 65 (1): 3–16. doi:10.1111/ppa.12439.

Tripp, R. 1996. "Biodiversity and Modern Crop Varieties: Sharpening the Debate." *Agriculture and Human Values* 13 (4): 48–63. doi:10.1007/BF01530523.

Tsegaye, B., and T. Berg. 2007. "Genetic Erosion of Ethiopian Tetraploid Wheat Landraces in Eastern Shewa, Central Ethiopia." *Genetic Resources and Crop Evolution* 54: 715–726. doi:10.1007/s10722-006-0016-2.

Uganda Bureau of Statistics. 2014. *The National Population and Housing Census 2014 – Area Specific Profile Series*. Kampala: UBOS. Accessed 7 December 2018. https://unstats.un.org/unsd/demographic/sources/census/wphc/Uganda/UGA-2016-05-23.pdf

Wairegi, L. W. I., P. J. A. Asten, K. E. Giller, and T. Fairhurst. 2016. *Banana–Coffee System Cropping Guide*. Nairobi: Africa Soil Health Consortium. Accessed 21 February 2019. https://core.ac.uk/download/pdf/132689625.pdf